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Modeling Multivariate Sensor Dynamics with STGNNs: An Anomaly Detection Study at the INFN CNAF Tier-1 Facility

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Modern data centres are cyber-physical infrastructures whose reliable operation depends on the continuous interaction of electrical and mechanical subsystems. Detecting anomalous behaviour in these environments is essential for ensuring operational continuity, improving energy efficiency, and enabling early fault prediction.

We present an anomaly-detection case study using Spatio-Temporal Graph Neural Networks (STGNNs) [1] to analyse signals collected at the INFN CNAF Tier-1 data centre, a high-throughput computing facility in Bologna, Italy. The Building Management System records electrical measurements from transformers and DRUPS units, as well as cooling-plant data such as chiller and pump power consumption, refrigerant pressures and temperatures, and water and air inlet/outlet temperatures.

Traditional statistical and machine-learning approaches often struggle to model the nonlinear dependencies and temporal dynamics present in such heterogeneous multivariate data. To address this challenge, we represent the sensor measurements as a dynamic graph in which nodes correspond to individual variables and edges capture evolving correlations or causal relationships. Such spatial-temporal graph can be described as a series of attributed graphs, which effectively represent (multivariate) time series data in conjunction with evolving structural information over time.

Our approach applies STGNNs to jointly encode spatial and temporal structure. The architecture combines graph-convolutional layers that aggregate information across related variables with recurrent temporal components that track system evolution over time. The spatial and temporal layers are trained jointly because the fused models are end-to-end differentiable. Factorized and coupled model variants exist, depending on the combination style of the spatial and temporal modules. Our unified modelling strategy is implemented through the PyTorch Geometric Temporal framework [2] and provides a robust foundation for anomaly detection for continuous monitoring of high-dimensional industrial sensor networks.

[1] Seo, Y., Defferrard, M., Vandergheynst, P., & Bresson, X. (2018, November). Structured sequence modeling with graph convolutional recurrent networks. In International conference on neural information processing (pp. 362-373). Cham: Springer International Publishing.
[2] Rozemberczki, B., Scherer, P., He, Y., Panagopoulos, G., Riedel, A., Astefanoaei, M., … & Sarkar, R. (2021, October). Pytorch geometric temporal: Spatiotemporal signal processing with neural machine learning models. In Proceedings of the 30th ACM international conference on information & knowledge management (pp. 4564-4573).

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